IJMSOR Vol. 3, Issue. 1
January - December, 2018

Application of the Bass Diffusion Model for Estimating the Lifecycle of a Retail Store[1]

Aplicación del Modelo de Difusión de Bass para estimar el Ciclo de Vida de una Tienda Minorista

DOI: https://doi.org/10.17981/ijmsor.03.01.01

Research Article - Reception Date: May 14, 2018- Acceptance Date: August 17, 2018

Jairo R. Coronado-Hernández, Alfonso R. Romero-Conrado, Carlos Uribe-Martes and Ricardo R. Calderón-Pérez
Industrial, Agro-Industrial and Operations Management Department. Universidad de la Costa. Barranquilla (Colombia).
jcoronad18@cuc.edu.co, aromero17@cuc.edu.co, curibe6@cuc.edu.co, rcaldero@cuc.edu.co

To reference this paper:
J. Coronado-Hernández, A.R. Romero-Conrado, C. Uribe-Martes, & R.R. Calderón-Pérez "Application of the Bass Diffusion Model for Estimating the Lifecycle of a Retail Store", *IJMSOR*, vol. 3, no. 1, pp. 5-10, 2018. https://doi.org/10.17981/ijmsor.03.01.01

Abstract-- This article presents a practical application of Lifecycle estimation using the Bass Diffusion Model in the case of a retail store. The results from the application of the model show that the probability that a person will buy driven by advertising is 5%, whereas the probability of buying based on the recommendation of another customer is 23%. According to the sales Lifecycle results, the store's monthly sales have stabilized and its market share is near its peak.

Keywords-- Diffusion model, business Lifecycle, Bass, estimation.

Resumen-- En el presente artículo se presenta una aplicación práctica para la estimación del ciclo de vida de una tienda minorista a través de la implementación del modelo de difusión de Bass. Al aplicar el modelo se obtiene que la probabilidad que una persona compre impulsado por publicidad es del 5%, mientras que la que compre por recomendación de otro cliente es del 23%. Al analizar el ciclo de venta del negocio se observa que este llegó a un nivel estable de ventas mensuales y se encuentra en auge dentro de la cuota de mercado que se tiene hasta el momento.

Keywords-- Modelos de difusión, ciclo de vida de un negocio, Bass, estimación.

1 This study is derived from the Program to Strengthen Citizenship and Democratic Culture CT+I through the IEP supported by ICT in the Department of Magdalena (CICLON)

I. Introduction

Diffusion models describe the behavior of new product sales over time. Numerous marketing research studies show that product sales Lifecycles follow a certain pattern over time, known as the S curve. An S curve means that new product sales initially grow quickly and later decrease slowly over time until reaching a plateau in market share.

Classical forecasting models are based on the extrapolation of data from historical product sales, but when no historical data is available, traditional forecasting techniques are not applicable [1]. An alternative is to use diffusion models, which are widely applied in marketing [2]. The purpose of a diffusion model is to estimate new product sales before their actual launch [3] when no historical sales information is available. [4]–[6] illustrate the application of diffusion models in supply chain management for short Lifecycle products that do not have a historical track record.

The purpose of this study is to demonstrate how to calculate the Lifecycle of a retail store, based on a case study of a retail store in the city of Barranquilla, using the Bass diffusion model to find the time at which its sales are expected to stabilize. The procedure consists in estimating the model's parameters to then generate the Lifecycle curve for the business. To this end, models will be used to generate the business's Lifecycle curve as an estimation to describe potential demand [7].

Diffusion model

Diffusion is the process through which an innovation propagates in a social system [8]. Diffusion models represent the form and speed at which innovations are adopted. Diffusion and adoption among the agents of a social system may occur because of both internal and/or external influences [9].

Agents who are externally influenced, known as innovators, are those who adopt an innovation independently, whereas as all other agents, known as imitators, are influenced by both external influences and the system's social pressures [9], which are generated by other agents who have previously adopted the innovation. Interpersonal communications, including non-verbal communications, substantially influence the speed of the diffusion process [10], because some agents adopt innovations as a result of social pressure [11]. The work of [2] includes a review of the different diffusion models and their various applications.

In diffusion theory, it is important to distinguish between the individuals who adopt innovations soon after their launch (called "innovators" or "early adopters") and those who adopt the innovation in later stages (called "followers" or "later adopters"), as shown in figure 1.

II. Methodology

In this study, the Bass diffusion model is used to model the Lifecycle of a retail store. This model was introduced by Bass in 1969, and it assumes that the adoption by agents depends not only on the internal influences of the system via social pressure but also on the external influences such as advertising. The variables and parameters used in the model are displayed in Table 1. These parameters may be estimated based on expert opinion, market research methods [3] or non-linear estimations if time series data is available.

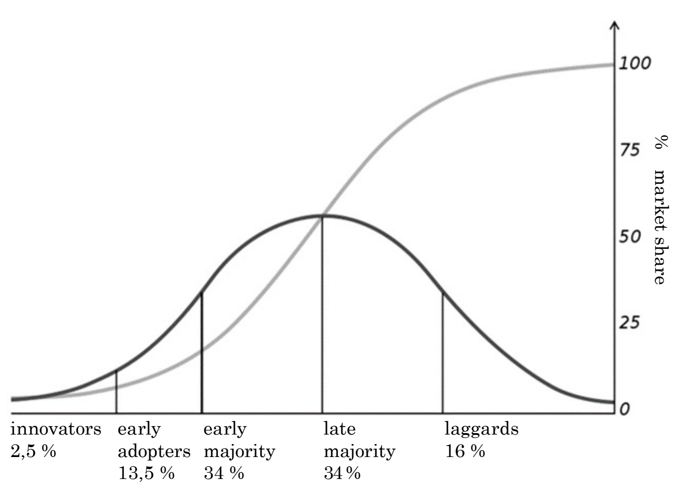

Figure 1. Diffusion of innovations
Source: Based on [11]

TABLE 1. MODEL VARIABLES AND PARAMETERS

N(t)	Fraction of agents who have adopted up to time *t*
p	Adoption rate of an innovator agent, or the probability of adoption by an agent externally influenced by advertising
q	Adoption rate of an imitator agent, or the probability of adoption by an imitator agent influenced by internal pressures of the system
m	Potential market

Source: Authors.

The model takes the form of a differential equation (1), the solution of which (2) shows the cumulative total of agents who have adopted the innovation at time *t*. It should be noted that the Bass model is the most used model in marketing for the estimation of innovation adoption. In this sense, the *p* coefficient is influenced by the marketing strategy used by a company.

$$\frac{dN(t)}{dt} = \left(p + qN(t)\right)\left(m - N(t)\right) \tag{1}$$

$$N(t) = m\frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}} \tag{2}$$

The starting point for predicting adoption is market research [3] and/or expert opinion, in order to estimate the model's parameters; subsequently, based on the adoption information, the model's parameters are recalculated [10]. Since it is not possible to estimate with certainty the potential market for a newly launched product [12], a variety of scenarios are used to describe potential demand [7]. The input parameters are estimated based on expert opinion [13], using the methodology suggested by [14] analogous products, or management judgments.

A. Estimation of parameters

When sales information is available, it is also possible to find the current Lifecycle stage of the product or innovation. [15] presents a non-linear estimation procedure for adjusting the Bass model parameters in order the minimize the estimation error of the model's parameters when initial sales information is available, compared to that proposed by [9] based on linear regression. The basic procedure consists in the following steps:

1. Input the data
2. Adjust the Bass diffusion model
3. Apply non-linear regression (NLS) to estimate *p*, *q* and *m*.

B. Generation of the product's Lifecycle

Following the algebraic process described by [9], it is demonstrated that sales S(t) at time t behave in the manner displayed in equation (3), as a function of the parameters *p*, *q* and *m*.

$$S(t) = pm + (q-p)N(t) - \frac{q}{m}(N(t))^2 \tag{3}$$

This function is implemented over a Lifecycle to estimate the expected sales or adoptions.

C. Computerized implementation for the estimation of parameters and generation of the product's Lifecycle

The estimation algorithm was implemented by means of the statistical software package R [16]. In the algorithm shown below, the data is input in line 1, the data is converted into a time series in line 2, and the units of time are set in line 3. In line 4, the non-linear model is created in memory. In line 5, the non-linear regression proposed in [15] is applied. In lines 6 to 14 the Bass model is introduced, using as input the coefficients estimated by the non-linear model in line 5.

Code in R for application of the Bass model

```
1   DATA<-c( data1, data2, ….)
2   Ventas <-ts(DATA)
3   time <- seq(from = 1,to = 7, by = 1)
4   Bass.Modelo <- Ventas ~ m * ((p + q)^2/p) * (exp(-(p + q) * time)/((q / p) *exp(-(p + q) * time)
    + 1)^2)
5   ParametrosBassModelo <-nls(formula = Bass.Modelo, start = c(p = 0.03, q = 0.1, m = max(Ventas)))
6   ModeloBass=function(p,q,m, T=100) {
7      S=double(T)
8      N=double(T+1)
9      N[1]=0
10     for(t in 1:T) {
11                          S[t]=p*m+(q-p)*N[t]-(q/m)*N[t]**2
12                          N[t+1]=N[t] + S[t]
13                         }
14     return(list(ventas=S, acumventas=cumsum(S)))
15     }
16  PLM<-ModeloBass(p,q,m, T=12)
```

D. Application to the case study

In March of 2017, a local retailer from the Atlantic Coast area in Colombia opened a new store in the city of Barranquilla, with 1600 m2 of sales floor area. In this case, following seven months of sales, the question is: At what stage of the Lifecycle is the business currently at?

Even though studies of this type are usually done with a greater number of periods, it initially provides an approximate market position of the business, as well as its stage in the Lifecycle, in addition to the impact of advertising and word-of-mouth marketing. The data provided by the company are displayed in table 2.

Table 2. Store sales in 2017

Month		Sales (COP[1])
1	March	1,643,000,000
2	April	2,825,382,898
3	May	2,616,600,000
4	June	2,705,700,000
5	July	2,711,500,000
6	August	2,711,500,000
7	September	2,846,186,279

Source: Authors.

The behavior of the sales data is show in Fig. 2.

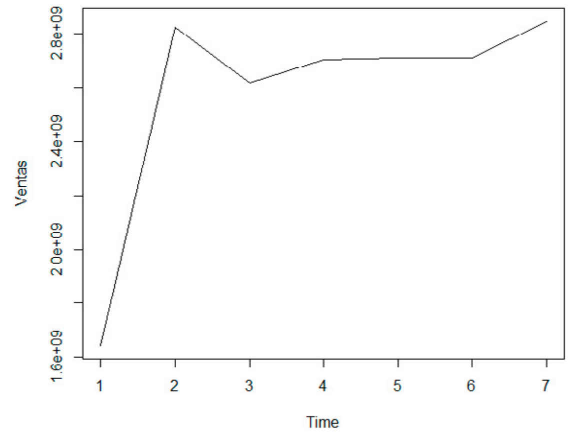

Figure 2. Company sales (by month)

The procedure yields the following estimated parameters of the model: p = 0.05189212, q = 0.2281213 and m = 33214792622 COP. This information indicates that the probability that a person in the target market will buy as a result of advertising is approximately 5%, the probable buy rate due to word of mouth is 23%, and the remaining percentage are people who are not expected to not buy.

```
Formula: Ventas ~ m * ((p + q)^2/p) * (exp(-(p + q) * time)/((q/p) * exp(-(p +
    q) * time) + 1)^2)

Parameters:
   Estimate Std. Error t value Pr(>|t|)
p 5.189e-02  1.030e-02   5.037   0.0073 **
q 2.281e-01  1.074e-01   2.124   0.1008
m 3.321e+10  1.036e+10   3.207   0.0327 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 338800000 on 4 degrees of freedom

Number of iterations to convergence: 9
Achieved convergence tolerance: 3.983e-06
```

Figure 3. Model results

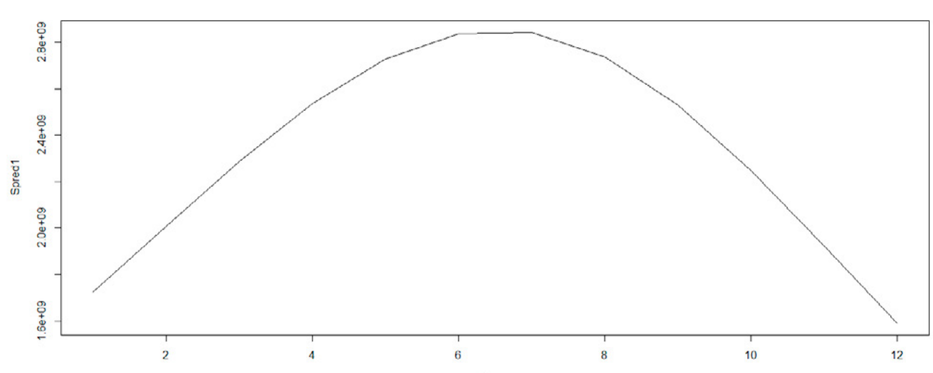

Figure 4. Diffusion of the store

[1] Colombian pesos

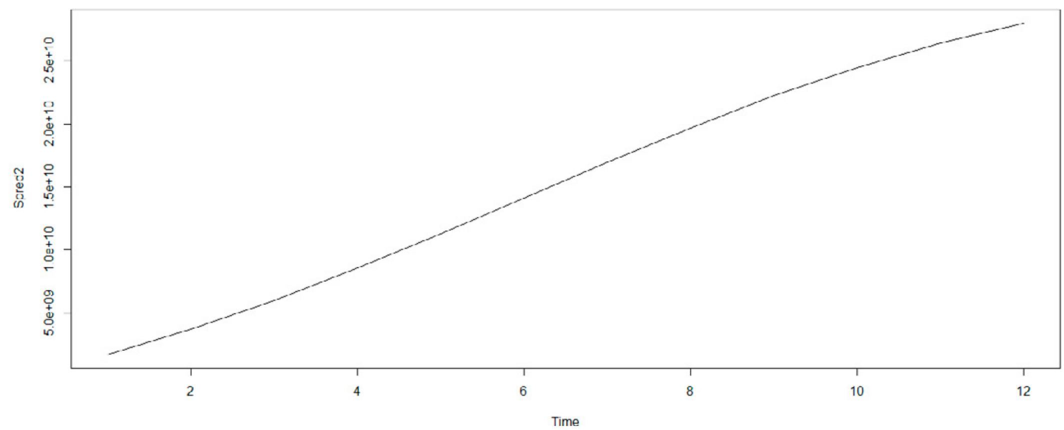

Figure 5. S diffusion curve

Following estimation of the parameters for the model, the diffusion model is run to estimate the Lifecycle of the business, as displayed in figures 3 and 4. Based on these, it can be said that the store is already at its peak: It has reached its maximum level of monthly sales of close to 2.8 billion Colombian pesos.

The company is advised to carry out a targeted campaign aimed at increasing sales in the area of influence in order to increase its market share.

V. Conclusions

Diffusion models are techniques used to forecast demand for products when no historical data is available.

The Bass diffusion model was applied to estimate the Lifecycle of a retail store.

It was found that the probability that a customer will buy in response to advertising is 5%, and the probability of buying based on word of mouth recommendations from other customers is 23%. Upon generating the curves of the model, it was found that the business's sales have stabilized.

Future research is expected to be performed on the effect on products with S curves when products are custom made through mass production in problems of combined models [17].

References

[1] J. Morrison, "Lyfe-Cycle Approach to new Product Forecasting," J. Bus. Forecast. Methods Syst., vol. 14, no. 2, pp. 3–5, 1995.

[2] N. Meade and T. Islam, "Modelling and forecasting the diffusion of innovation - A 25-year review," International Journal of Forecasting Twenty five years of forecasting, vol. 22, no. 3. pp. 519–545, 2006.

[3] R. Scitovski and M. Meler, "Solving parameter estimation problem in new product diffusion models," Appl. Math. Comput., vol. 127, no. 1, pp. 45–63, 2002.https://doi.org/10.1016/S0096-3003(00)00164-8

[4] J. R. Coronado-Hernández, J. P. García-Sabater, J. P. Maheut, and J. J. Garcia-Sabater, "Modelo de optimización estocástica para la planificación de cadenas de suministro para productos con ciclo de vida cortos," in 4th International Conference On Industrial Engineering and Industrial Management, 2010.

[5] J. R. Coronado-Hernández, "Análisis del efecto de algunos factores de complejidad e incertidumbre en el rendimiento de las Cadenas de Suministro. Propuesta de una herramienta de valoración basada en simulación.," Universitat Politècnica de València, Valencia (Spain), 2016.https://doi.org/10.4995/Thesis/10251/61467

[6] A. R. Romero-Conrado, "Algoritmo heurístico basado en listas tabú para la planificación de la producción en sistemas multinivel con listas de materiales alternativas y entornos de coproducción," Universidad de la Costa, 2018.

[7] Z. L. Chen, S. Li, and D. Tirupati, "A scenario-based stochastic programming approach for technology and capacity planning," Comput. Oper. Res., vol. 29, no. 7, pp. 781–806, 2002. https://doi.org/10.1016/S0305-0548(00)00076-9

[8] E. M. Rogers, "Social Structure and Social Change," Am. Behav. Sci., vol. 14, no. 5, pp. 767–782, 1971. https://doi.org/10.1177/000276427101400508

[9] F. Bass, "A New Product Growth for Model Consumer Durables," Manage. Sci., vol. 15, no. 5, pp. 215–227, 1969. https://doi.org/10.1287/mnsc.15.5.215

[10] V. Mahajan, E. Muller, and F. Bass, "Diffusion of New Products: Empirical Generalizations and Managerial Uses," Mark. Sci., vol. 14, no. 3, pp. 79–88, 1995. https://doi.org/10.1287/mksc.14.3.G79

[11] E. M. Rogers and T. F. Press, Diffision of Innovations. New York, 1983.

[12] C. V Trappey and H. Y. Wu, "An evaluation of the time-varying extended logistic, simple logistic, and Gompertz models for forecasting short product lifecycles," Adv. Eng. Informatics, vol. 22, no. 4, pp. 421–430, 2008. https://doi.org/10.1016/j.aei.2008.05.007

[13] M. Lawrence, P. Goodwin, M. O'Connor, and D. Ínkal, "Judgmental forecasting: A review of progress over the last 25áyears," International Journal of Forecasting Twenty five years of forecasting, vol. 22, no. 3. pp. 493–518, 2006.

[14] V. Mahajan and S. Sharma, "A simple algebraic estimation procedure for innovation diffusion models of new product acceptance," Technol. Forecast. Soc. Change, vol. 30, no. 4, pp. 331–345, 1986. https://doi.org/10.1016/0040-1625(86)90031-4

[15] V. Srinivasan and C. H. Mason, Nonlinear least squares estimation of the Bass diffusion model of new product acceptance. Graduate School of Business, Stanford University, 1984.

[16] Rd. C. Team, "R: A language and environment for statistical computing," ISBN 3-900051-07-0. R Foundation for Statistical Computing. Vienna, Austria, 2013. url: http://www. R-project. org, 2005.

[17] M. Valero-Herrero, J. P. Garcia-Sabater, J. R. Coronado-Hernandez, and J. P. Maheut, "Planteamiento dinámico del problema de secuenciación en líneas de montaje con mezcla de modelos," in XV Congreso de Ingeniería de Organización // 5th International Conference on Industrial Engineering and Industrial Management, 2011, pp. 288–296.

[18] A. R. Romero-Conrado, L. J. Castro-Bolaño, J. R. Montoya-Torres, and M. Á. Jiménez Barros, "Operations research as a decision-making tool in the health sector: A state of the art," DYNA, vol. 84, no. 201, p. 129, May 2017.

[19] C. Saavedra Sueldo, S. Urrutia, D. Paravié, C. Rohvein, y G. Corres, Una propuesta metodológica para la determinación de capacidades estratégicas en pymes industriales, INGE CUC, vol. 10, n.º 2, pp. 43 - 50, dic. 2014.

[20] C. Ayala, Desarrollo de Estrategias de Responsabilidad Social Universitaria, Módulo Arquitectura CUC, vol. 13, n.º 1, pp. 67-86, jul. 2014.